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ABOUT THIS ISSUE

Peering into crystal balls, even cloudy ones, is an almost irresistible human impulse. In *What Next?* we look at the problem of predicting the future based on information about the past. The statistical tools we show you how to use include linear least squares fit and calculating coefficients of correlation. We also cover some of the implications of the REPLICATE command (/R) and how to use it in differing circumstances. Even if you never use the VisiCalc® program for making predictions, you should go through the first section of *What Next?*, called "Calculating a Quarterly Ratio Index," to familiarize yourself or refresh your memory about /R. The article also covers @AVERAGE, @COUNT, @SUM, and @SQRT.

In *Calculating Chi-Square,* we look at another problem that, like the one in *What Next?,* is solved with statistics. The example we've used for this article is a manufacturer who wants to know how long he should guarantee his product. The problem that has to be solved is knowing whether the sample batch of products tested is representative of all the products built. The statistical technique that helps answer that question is the Chi-square test. Among the functions of the VisiCalc program you will find applied in this article are @EXP, @PI, and @SQRT.

There's been a rush of books published lately about the VisiCalc program. We have listed them in earlier issues. In this issue we are reviewing one of them, and will review others in future issues.

In *Another Look at VisiCalc Advanced Version,* we show how one of the new features of the Advanced Version, @DOTPRODuct, can be used with the sheet developed for *What Next?* There's also an introduction to some of the refinements of the REPLICATE command and the new ATTRIBUTE command. With regard to the latter, we show how to display the expressions on your worksheet.

This issue also includes the second installment of our Related Products column.

We wish to thank Business and Professional Software of Cambridge, Mass. for their assistance with this issue. Figures 1, 2, and 8 were plotted and drawn for us by BPS using VisiCalc files and Apple Business Graphics, which BPS developed.

Market Research Results

We recently sent questionnaires to nearly 3800 of you, asking for an evaluation of SATN. We, and the market research firm that conducted the study for us, were both surprised and gratified by the return. We received responses from 1477 readers, a remarkable 39%.

Here are a few of the results that we have the space to share with you:

First, the largest proportion of you, 66%, use Apple IIs, 11% use Radio Shack Model 1s, 10% Apple ///s, and 8% each IBMs and Radio Shack Model 3s. All other machines share 11%.

A large minority, almost 30%, regard SATN "very favorably." Only 4% regard us "unfavorably" and the rest, 51%, regard us "somewhat favorably."

Twenty percent of the respondents think SATN is too mathematical, 17% say it's not mathematical enough, and 58% rank it as "just right." The breakdowns are similar for the questions of whether SATN is

KEY TO CONVENTIONS USED IN SATN

The VisiCalc® program is available on personal computers manufactured by Apple, Atari, Commodore, Hewlett-Packard, IBM, and Radio Shack. To reduce any confusion arising from the differences among the keyboards of those computer systems, SATN uses a standard symbol and name to represent certain commonly used keys.

The symbol ® and the word RETURN are used as synonyms for the keys known as ENTER, ENDLINE, and RETURN. The symbol ^ is used to represent an exponentiation operator.

To make VisiCalc documentation more readable, the program was designed so that the colon (:) has the same effect as RETURN in some commands, as when ending the > command or separating various elements of the replicate command.

In examples of what to type, type exactly what you see and press RETURN at the end of every line. Users of the HP-83/85 may find it necessary to add parentheses to some of the expressions included in the text. For example, 3+4*5 should be (3+4)*5 on an HP-83/85.

Throughout SATN, one typeface represents both VisiCalc input and output (what you should type and what you will see on the screen). The typeface looks like this:

```
    This line is typeset in OCR-B.
    So is this: +A1+B1*3.25
```

To allow you to type the formulas directly on a VisiCalc sheet, examples in SATN specify coordinates, like A1, rather than the names of the values they represent. When actually typing a formula, you can use the arrows to point rather than using the > command.

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"too simple and easy" (18%) or "too difficult to get all the way through" (18%) and "has too many details" (12%) or "doesn't give enough details" (18%). The "just right" answers to those questions were 60% and 65% respectively.

Asked whether SATN has too many pictures and illustrations, however, 25% of you responded negatively and only 4% positively. Consequently, we are trying to work in a few more screen photos or illustrations in each issue.

We had already planned the Related Products and Related Publications columns when the questionnaires went out in the mail, so we were reassured by the overwhelmingly strong interest the questionnaire has turned up regarding those features. Those who are "very interested" in such information amount to 68%, while another 23% are "somewhat interested." Only 7% fell into the "uninterested" categories.

Finally, based on the question concerning your purchasing plans for systems, we estimate that SATN readers (not counting the one who reported that he would buy 10,000 of one brand of microcomputer) will buy approximately a quarter of a billion dollars' worth of hardware in the next six months. That is impressive.

WHAT NEXT?

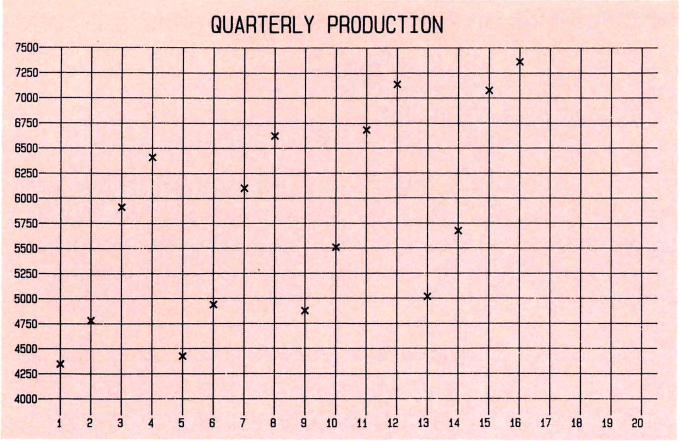
Although the VisiCalc® program is widely used to answer "what if," one of the more intriguing classes of question has always been "what next?"

"What next" questions usually assume that the future will resemble the past in some ways. If things have been going badly, they will get worse; if they've been looking up, they will get even better. Over the very long term either assumption may be dangerously misleading, but for short term purposes they are usually safe.

In this article we will look at several related techniques for predicting what the future will look like if the past is any guide. Indeed, one of the points we will cover is one way of determining whether the past really is a reliable guide. The key technique we shall show is called a "linear least squares fit," which is a form of "regression analysis." The problem with most of what we have seen concerning the use of the VisiCalc program to solve this problem is that the data used usually consists of neat, clean progressions, up or down. The data we will use recognizes that, given appropriate periods, the numbers may fluctuate widely.

The scatter graph in Figure 1 plots the data we will use. For illustration's sake, assume that the graph plots quarterly production of some product. The products could be anything, of course, from snap fasteners to paper plates to program diskettes. When we connect the points, as in Figure 2, the regularity of the data is apparent from the sawtoothed appearance of the resulting line. Note though, that Figure 2 contains 20 data points, four more than Figure 1. Using exactly the values used to produce the plot for Figure 1, we performed a linear regression to predict the 17th through the 20th quarters. Clearly, the four predicted quarters do not accurately reflect the pattern of the last 16 quarters.

What we must do is to smooth the seasonal fluctuations; calculate the regression; then make the resulting



Courtesy BPS, Inc.

FIGURE 1. *This scatter graph plots the points of the data shown in B4 . . . B19 of Figure 3.*

predictions reflect seasonal variations.

We'll briefly examine one method of adjusting for seasonal fluctuations, a quarterly ratio index. Although there are other, more sophisticated ways to smooth the data, we chose this method because it allows us to review several points about the /R command.

Calculating a Quarterly Ratio Index

To begin with, set up your sheet with the command:

```
/GOR
```

Next, enter the labels and data in columns A and B, cells A1 . . . A19 and B1 . . . B19, as shown in Figure 3.

In column C enter:

```
>C4:/FI@AVERAGE(B4 . . . B7)
```

That gives the average quarterly production for the first four quarters of the sequence we are considering. For the remaining quarters we have only to replicate the entry at C4 into C8, C12, and C16. Notice, though, that the cells between those entries must remain blank. To do that we must replicate the original entry in two steps. Enter:

```
>C4:/R:C8:RR
>C4:/R . . . C8:C12:RRRR
```

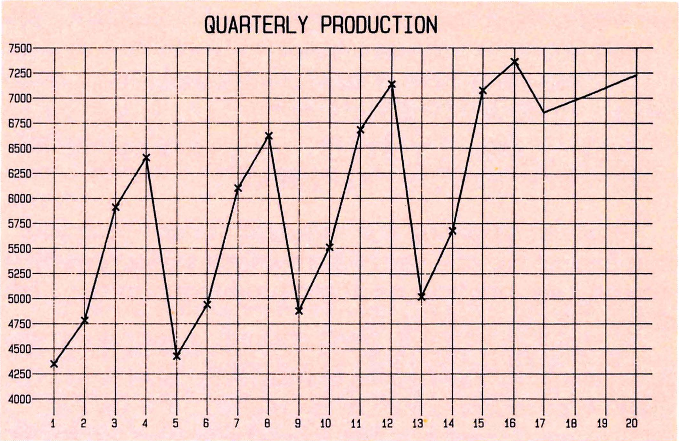
Had we replicated C4 directly into C8 . . . C12, all the intervening blanks would have been filled with unnecessary calculations, and would have to be blanked out.

Given the averages just calculated and the raw quarterly data, we derive the quarterly index by dividing each quarter's actual production by the quarterly average for the year. Enter and replicate:

```
>D4:/F$+B4/C4
>D4:/R:D5 . . . D7:RN
```

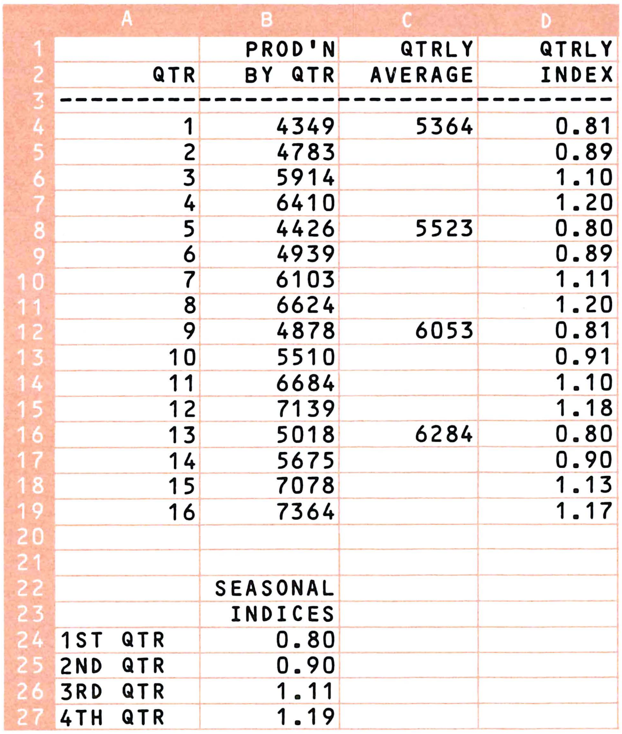
The effect of those entries is to produce the basic calculations for extension into the remaining cells in the range from D8 through D19. You cannot replicate the first expression into the entire range because, beginning at D8, the divisor must change. Replicating +B4/C4 and referencing B4 relatively (R) and C4 no change (N), would be to divide every quarter by the average for the first four. Making both references relative would produce ERRORs for the indices in the 2nd, 3rd, and 4th quarters because you would be dividing by blank cells at C5 . . . C7 (and the corresponding cells in column C) and those blanks are read by the VisiCalc program as zeros. However, once we have established the calculation for each of the first four quarters, we can expand that sequence to eight and then to 16 with two replications. Enter:

```
>D4:/R . . . D7:D8:RRRRRRRR
>D4:/R . . . D11:D12:RRRRRRRRRRRRRRRR
```



Courtesy BPS, Inc.

FIGURE 2. *When the points in Figure 1 are connected with a line and the next four quarters projected, this is the resulting plot.*



	A	B	C	D
1		PROD'N	QTRLY	QTRLY
2	QTR	BY QTR	AVERAGE	INDEX
3	----------	----------	----------	----------
4	1	4349	5364	0.81
5	2	4783		0.89
6	3	5914		1.10
7	4	6410		1.20
8	5	4426	5523	0.80
9	6	4939		0.89
10	7	6103		1.11
11	8	6624		1.20
12	9	4878	6053	0.81
13	10	5510		0.91
14	11	6684		1.10
15	12	7139		1.18
16	13	5018	6284	0.80
17	14	5675		0.90
18	15	7078		1.13
19	16	7364		1.17
20				
21				
22		SEASONAL		
23		INDICES		
24	1ST QTR	0.80		
25	2ND QTR	0.90		
26	3RD QTR	1.11		
27	4TH QTR	1.19		

FIGURE 3. *Columns A and B contain the raw data from which the entire sheet is built. Notice, by the way, that the labels in rows 1, 2, 22, and 23 are set with /FR, while those in A24 . . . A27 are not locally formatted.*

Next, we generate a single set of SEASONAL INDICES for each of the four quarters. To do that we take an average of all first, second, third, and fourth quarters calculated in column D. Enter:

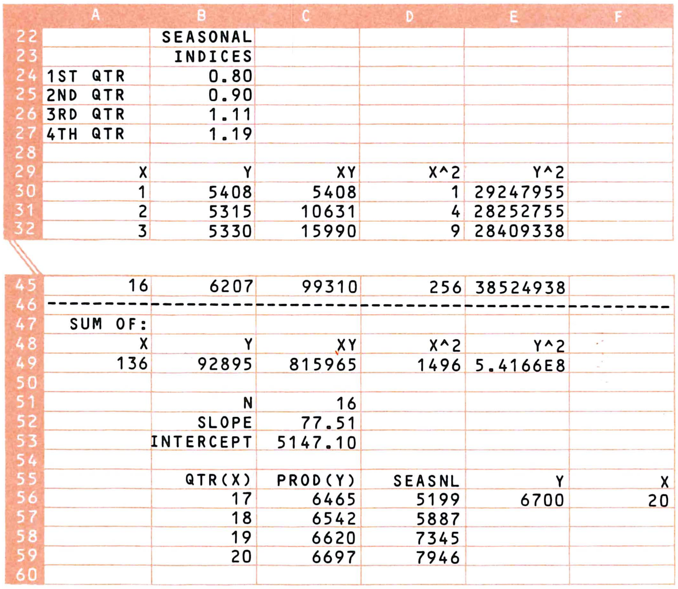
```
>B24:/F$@AVERAGE(D4,D8,D12,D16)
>B24:/R:B25 . . . B27:RRRR
```

Now, by applying the index to the actual production figures we can create a smoothed series on which we can base predictions about production in the 17th and subsequent quarters.

In Figure 4 we have entered the labels X, Y, XY, X^2, and Y^2. The figures beneath the label X are the quarter numbers, and can be replicated from A4 . . . A19 above. Under Y is the smoothed series produced by applying the seasonal index to the quarterly production figures in B4 . . . B19. Since we must apply the same indices repeatedly, that is, we must go back to the beginning of the index range with every fourth calculation, we cannot calculate the entire column in a single replication. Enter and replicate:

```
>B30:/FI+B4/B24
>B30:/R:B31 . . . B33:RR
>B30:/R . . . B33:B34:RNRNRNRN
>B30:/R . . . B37:B38:RNRNRNRNRNRNRNRN
```

Notice that, as when we calculated the seasonal indices in D4 . . . D19, each replication of the sequence doubles the number of cells filled in.



	A	B	C	D	E	F
22		SEASONAL				
23		INDICES				
24	1ST QTR	0.80				
25	2ND QTR	0.90				
26	3RD QTR	1.11				
27	4TH QTR	1.19				
28						
29	X	Y	XY	X^2	Y^2	
30	1	5408	5408	1	29247955	
31	2	5315	10631	4	28252755	
32	3	5330	15990	9	28409338	
45	16	6207	99310	256	38524938	
46	----------	----------	----------	----------	----------	----------
47	SUM OF:					
48	X	Y	XY	X^2	Y^2	
49	136	92895	815965	1496	5.4166E8	
50						
51		N	16			
52		SLOPE	77.51			
53		INTERCEPT	5147.10			
54						
55		QTR(X)	PROD(Y)	SEASNL	Y	X
56		17	6465	5199	6700	20
57		18	6542	5887		
58		19	6620	7345		
59		20	6697	7946		
60						

FIGURE 4. *To minimize recalculation time, we produced the columns for X^2 and Y^2 without the exponentiation operator. Instead we used* A30∗A30 *and* B30∗B30, *which we replicated into the cells below. It takes the program a bit longer to raise to powers than to perform multiplication. When only one or two exponential calculations are needed there's not usually a time problem. When over thirty must be performed they can add significantly to recalculation time.*

The columns under XY, X^2, and Y^2 are calculated from X and Y with the entries:

```
>C30:/FI+A30*B30
>D30:/FI+A30*A30
>D30:/R:E30:RR
>C30:/R . . . E30:C31 . . . C45:RRRRRR
```

We will use the values in the first four of those columns, (X, Y, XY, and X^2) to calculate the data points for quarters 17 through 20. The Y^2 column will not enter into our analysis until we reach the final part of this article.

Performing a Linear Least Squares Fit

The manuals for calculators that have built-in statistical functions sometimes present the equations for performing a least squares fit with no explanation at all of what the different terms in the equations mean. The effect, whether intentional or not, is to intimidate and impress the user. In fact, most of what is done is relatively straightforward and can be explained simply.

To begin with, a linear least squares fit is an equation that describes a line. The line described is the one around which most of the data points are clustered at a minimum distance. Not all points are equidistant from the line, but relative to all the other points, the distance of any one point from the line is minimal.

There are two elements to the description of the line, its "slope" and its "intercept." The slope of a line is defined by one equation, the intercept by another. In Figure 5 we show the plot of a line as well as the relevant equations. Notice in the figure that the intercept is along the Y axis of the graph and the quarters of production along the X axis. Each data point, then, can be described by a data pair consisting of an X and Y.

Once the slope and intercept of the line have been determined, it is possible to project the line and determine where future data points will lie on the graph. Similarly, once the numerical values of the slope and intercept have been found they can be substituted into very simple equations to predict further points along the line. The equations shown in Figure 5 use standard mathematical symbols. If we convert those equations into the terms used in the VisiCalc program we can grasp them more readily.

First, the general expression to calculate the slope of a line is:

$$SLOPE = \frac{N * @SUM(XY) - (@SUM(X) * @SUM(Y))}{N * @SUM(X^{\wedge}2) - (@SUM(X)^{\wedge}2)}$$

where N is the number of data pairs under consideration.

Clearly, we shall have to total the columns we have labelled X, Y, XY, X^2, and Y^2, so enter:

```
>A49:@SUM(A30 . . . A46)
>A49:/R:B49 . . . E49:RR
```

Since N, one of the first elements in the expression to calculate the SLOPE, is the number of data pairs, we must count the entries in column A. Enter:

```
>C51:@COUNT(A30 . . . A46)
```

If your version of the VisiCalc program does not have the @COUNT function, you can use the value displayed at A45 or even enter the number of data pairs as

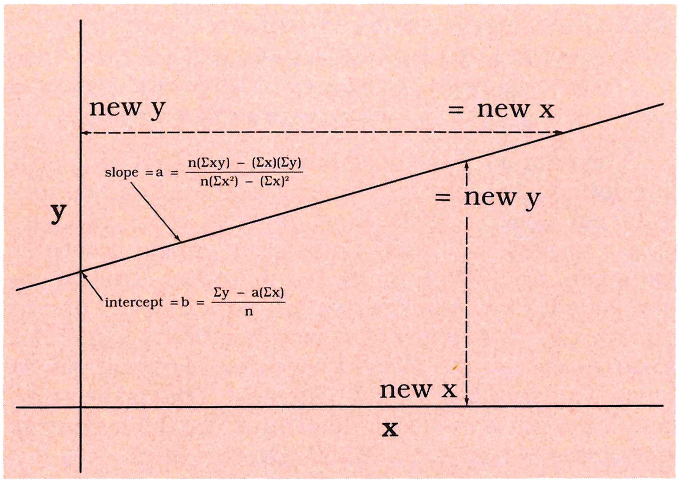

new y
= new x
slope = a = $\frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2}$
y
= new y
intercept = b = $\frac{\Sigma y - a(\Sigma x)}{n}$
new x
x

FIGURE 5. *The symbol Σ is the equivalent of @SUM in VisiCalc.*

a number.

In the expression just entered and in those used to total the columns, you'll notice that we included the repeating label command entered on row 46. The @SUM function of the VisiCalc program saw the label as a zero and the @COUNT saw it as a blank. In both cases, the inclusion of the label at the ends of the ranges allows us to insert additional rows at the bottom of the column if more data is desirable or necessary. (We should add that if the elements counted by the @COUNT function are separated by commas, that is, form a list, then the label would be included in the count and given a value of 1.)

Having calculated *N*, we can calculate the slope of the line defined by the data points. Enter:

```
>C52:/F$+C51*C49-(A49*B49)/(C51*D49
      -(A49*A49))
```

Your sheet should show 77.51 as the slope of the line. To calculate the intercept we use the calculation of the slope as shown in the general formula:

$$INTERCEPT = \frac{@SUM(Y) - (SLOPE * @SUM(X))}{N}$$

On our sheet that expression is entered:

```
>C53:/F$+B49-(C52*A49)/C51
```

That should give you 5147.10.

Having calculated the slope and intercept the next step is to predict the 17th through the 20th quarters. Since quarters are the X variable and production is the Y variable we need the formula that calculates Y. That is:

$$Y = SLOPE * X + INTERCEPT$$

Then, given an X, find Y by entering:

```
>B56:17
>B57:1+B56®/R:B58 . . . B59:R
>C56:/FI+C52*B56+C53
>C56:/R:C57 . . . C59:NRN
```

The first two of those entries produces the sequence 17 . . . 20 for the quarter numbers. The next two entries produce the sequence 6465, 6542, 6620, and 6697 as shown in Figure 4. Although they are valid data points given the sequence from which they have been derived, those values must now be adjusted to reflect the seasonal nature of the original set of data points. Since the 17th quarter in the sequence is the first quarter of a year, we can perform a simple replication to produce the seasonal predictions of production. Enter:

```
>D56:/FI+C56*B24
>D56:/R:D57 . . . D59:RR
```

If those points were plotted they would reflect the sawtooth that is characteristic of the raw data points.

Should you want to calculate the quarter in which production will reach a certain level, use the general formula for finding X, which is:

$$X = \frac{Y - INTERCEPT}{SLOPE}$$

which is entered on our sheet:

```
>E56:6700
>F56:+E56-C53/C52
```

Of course, the value that is calculated at F56 is the "smoothed" 20th quarter and as with the values in D56 . . . D59 must be adjusted by the appropriate seasonal factor.

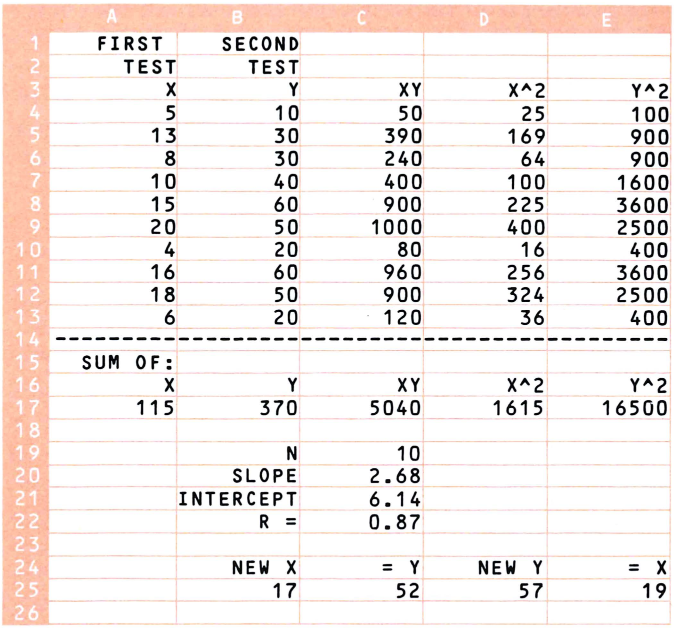
The expressions already on the sheet should show the new number, slope, and intercept as well as the predicted values for the 17th through 20th quarters.

Coefficients of Correlation

There are times when the relationship between X and Y is not as clearly defined as it is in the example we have used. In order to test the relationship we can calculate the correlation between the two variables. The test yields a value that falls between −1 and 1. The nearer to 1 the greater the likelihood that the two variables are positively dependent on each other. If near −1, the variables are inversely related (that is, as one rises the other falls), and, if near zero, nearly completely independent. In any event, a coefficient of correlation near 1 or −1 can't reasonably be interpreted to mean that X causes Y or vice versa, only that they are likely to be associated.

The sheet shown in Figure 6 is an edited version of the ones used in our earlier examples. The labels have been slightly changed, but all the expressions on row 17 differ from the ones in Figure 4 only with regard to the ranges the @SUMs refer to. Similarly, the expressions for the calculations of N, SLOPE, and INTERCEPT differ only regarding their value references. Since we deal only with 10 data points, the ranges in the @SUM expressions on row 17 should be adjusted to rows 4 . . . 14. You can recreate this sheet merely by deleting all the averaging calculations from the sheet you developed earlier for this article and by substituting the values we show for X, FIRST TEST, and Y, SECOND TEST.

The data that we have entered are hypothetical scores given to employees when they applied for their jobs (X) and after six months' experience (Y). The tests are given to find out whether the first score can be used to predict achievement in certain skills after some period of employment. Alternatively, X could be sales



	A	B	C	D	E
1	FIRST	SECOND			
2	TEST	TEST			
3	X	Y	XY	X^2	Y^2
4	5	10	50	25	100
5	13	30	390	169	900
6	8	30	240	64	900
7	10	40	400	100	1600
8	15	60	900	225	3600
9	20	50	1000	400	2500
10	4	20	80	16	400
11	16	60	960	256	3600
12	18	50	900	324	2500
13	6	20	120	36	400
14	---------	---------	---------	---------	---------
15	SUM OF:				
16	X	Y	XY	X^2	Y^2
17	115	370	5040	1615	16500
18					
19		N	10		
20		SLOPE	2.68		
21		INTERCEPT	6.14		
22		R =	0.87		
23					
24		NEW X	= Y	NEW Y	= X
25		17	52	57	19
26					

FIGURE 6. *Compare this Figure to Figure 3.*

calls made per day and Y sales in hundreds of dollars.

The coefficient of correlation, R, is calculated at C22. In general terms the expression is:

$$R = \frac{N*@SUM(XY) - (@SUM(X)*@SUM(Y))}{@SQRT(N*@SUM(X^{\wedge}2) - @SUM(X)^{\wedge}2)*@SQRT(N*@SUM(Y^{\wedge}2) - @SUM(Y)^{\wedge}2)}$$

On our sheet it is entered:

```
>C22:/F$+C19*C17-(A17*B17)/
     (@SQRT(C19*D17-(A17*A17))*
     @SQRT(C19*E17-(B17*B17)))
```

The data we have used shows that there is a high correlation (.87) between the scores on the first and second tests. Given a NEW X, or first test score, of 27 as shown at B25, we could reasonably expect a second test score, or NEW Y, of 79. On the other hand, if we were looking for an employee whom we would like to achieve the proficiency that is indicated by a score of 65 on the second test (NEW Y), we should expect him or her to score around 22 on the first test. That is the same calculation as we used to determine in which quarter production would reach 6700. On this sheet it is entered as:

```
>E25:+D25-C21/C20
```

There are many situations in business, education, or government in which the techniques we have developed here may be used. "What next?" is one of the perennially interesting questions we ask or are asked. Unfortunately, space doesn't permit us to deal with some of the more complex cases, as when the data fits a curve rather than a straight line. That's very often the case, and such problems can be solved with the VisiCalc program as we shall show in a future issue.

BOOK REVIEW

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An Introduction to VisiCalc Matrixing for Apple and IBM

by Harry Anbarlian, McGraw-Hill Book Company, New York, NY, 252 pp., $22.95

Reviewed by Stuart A. Forsyth.

VisiCalc®—the grandaddy of spreadsheet programs—is the best-selling software program for microcomputers. It replaces paper, pencil, and calculator with a flexible, interactive electronic worksheet; and it does so in a subtly sophisticated manner which rises to the level of a microcomputer language. Part of its popularity is based on the users' ability to customize the program's power for their particular applications.

But how does one learn to use VisiCalc? Some persons are able to avoid that task by employing templates or models designed by others. But many want to build their own models, or at least modify those already designed for them. The traditional means of learning have been user manuals, tutorials, sample templates, and personal training.

Harry Anbarlian has a different idea. He believes that one can learn to use VisiCalc by constructing a number of different matrices (or templates, or models, as they are called in other books) that embody the fundamental concepts of VisiCalc, have varying levels of difficulty, and are diverse and useful. It is an admirable goal and a tall order. He brings it off well.

A clear and concise introduction affords the reader an understanding of the book's purpose, organization, and use as a hands-on learning aid. It is intended to be used interactively with VisiCalc running on the reader's microcomputer. By page 11 the reader is ready to boot VisiCalc. The requisite foundation for using VisiCalc is built in the next 22 pages where the author introduces the matrix concept using a "boxes on a blackboard" analogy and explains the key VisiCalc commands in both Apple and IBM-PC dialects.

After only 40 pages the reader is ready to start using VisiCalc—without wading through user manuals or tutorials. Now the fun begins.

The examples are broken into two sections, one for Apple users and another for IBM-PC users. Each section contains nine exercise matrices, arranged in groups of three according to complexity.

The simple matrices are: petty cash voucher, appointment calendar, credit card record, price earning ratio, inventory cost, and organization chart (yes, a titles-in-boxes-connected-by-lines organization chart done on VisiCalc without a single mathematical calculation!).

The moderately complex matrices are: treasury bill investment yield, payroll, construction trades equal employment opportunity, student's budget, education/selection impact ratio, and travel expense voucher.

The complex matrices are: bar graph, electric bill, zero base budget, departmental age analysis, cost/sales comparative bar graph, and stock portfolio.

Each is thoroughly explained, containing a clear statement of the objective, an explanation of how the task is accomplished by hand without VisiCalc and a microcomputer, and step-by-step instructions for creating the VisiCalc matrix. Each also includes an illustration of the completed blank matrix, an example of how to use it, steps for inserting data, and an illustration of the completed matrix with data and resultant calculations. To ensure that the matrices work and are free from defects, the author enlisted his wife—who had no knowledge of microcomputers or VisiCalc—to test each matrix.

While the examples in each section have been tailored to the keyboard of either the Apple II or the IBM-PC, the author has furnished enough information to enable even the novice Apple II user to explore, learn from, and use matrices from the IBM-PC section, and vice versa. Apple /// users likewise should have no problem. Using the examples on other microcomputers may require a little more familiarity with VisiCalc commands in order to adapt the matrices.

There is plenty of meat in this fine work. There is also an unusual and outstanding dessert, in the form of a final section on how to create polished matrices by inserting lines, spaces, titles, names, and dates and on consolidating and printing matrices. This seldom discussed topic takes the VisiCalc user all the way to a professional looking printed result.

The author's VisiCalc credentials include extensive personal use and user group experience. As a member of the Big Apple Users Group in New York City, he originated and was chairman of its VisiCalc Users Sub-Group. Along the way he learned to teach and write very well, and readers benefit immeasurably from his clear, well organized presentation.

For new users, *An Introduction to Matrixing for Apple and IBM* is an excellent alternative to the traditional ways of learning to use VisiCalc. It may even be better because it teaches painlessly, maintaining a high level of excitement and rewarding the reader with useful results, quickly obtained. While it is not designed to replace user manuals, it will make them more intelligible by serving as an experience building introduction to them.

Even experienced VisiCalc users may learn much from this work. The variety and imaginative selection of topics for the eighteen matrices means there is a good chance that even the most tenured user will find fresh ideas and techniques.

As just an introduction to VisiCalc, this book is excellent. But it achieves even more by also being a source of creativity and excitement in the use of VisiCalc. Following an introduction to VisiCalc in this book, users may well find themselves continuing to turn to it as a resource and reference (yes, there is an index). The author has not only achieved, but also transcended his stated purpose—to the lasting benefit of his readers.

Stuart A. Forsyth is Director of the Office of the State Bar Court of the State Bar of California.

Calculating Chi-Square

Analyzing the reliability of measurements, whether of the size of a table, voltage from a power source, or dimensions of machined parts, commonly calls for the use of statistics. In this article we are going to show you how to use the VisiCalc® program and in particular some of its mathematical functions to do a statistical analysis of a problem.

Imagine that you manufacture pocket calculators and have to set the warranty period for your product. Before you make that decision you have to examine how your calculators fail over time. You can't examine all the calculators you produce, so you decide to test a sample of 100. One of the problems is knowing whether your sample is any good, whether the pattern of failures among the 100 accurately reflects the pattern of all the calculators you produce. That's what the Chi-square test can help determine.

Before you can validate your sample, though, you must find two other values: the mean, and the standard deviation.

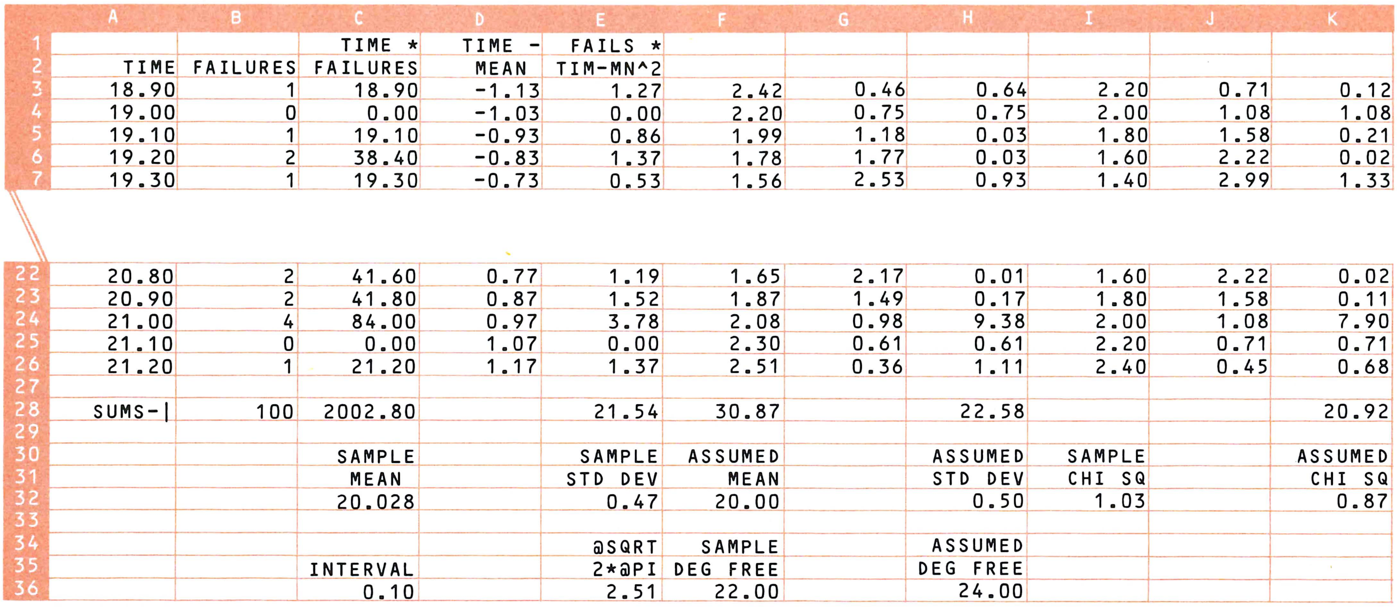
Mean and Standard Deviation

Table 1 contains the results of the test of the 100 calculators. The table shows that the first of them failed at 18.9 months, the last at 21.2 months. That span is shown in the first column in 0.1 month intervals. The second column shows the number of failures observed during each interval. Table 1 is the basis of the VisiCalc sheet shown in Figure 7. To set the sheet up, enter the global format command:

```
/GF$
```

TABLE 1.

TIME	FAILURES
18.90	1
19.00	0
19.10	1
19.20	2
19.30	1
19.40	4
19.50	3
19.60	9
19.70	8
19.80	11
19.90	9
20.00	5
20.10	7
20.20	8
20.30	9
20.40	6
20.50	3
20.60	2
20.70	2
20.80	2
20.90	2
21.00	4
21.10	0
21.20	1



	A	B	C	D	E	F	G	H	I	J	K
1			TIME *	TIME -	FAILS *						
2	TIME	FAILURES	FAILURES	MEAN	TIM-MN^2						
3	18.90	1	18.90	-1.13	1.27	2.42	0.46	0.64	2.20	0.71	0.12
4	19.00	0	0.00	-1.03	0.00	2.20	0.75	0.75	2.00	1.08	1.08
5	19.10	1	19.10	-0.93	0.86	1.99	1.18	0.03	1.80	1.58	0.21
6	19.20	2	38.40	-0.83	1.37	1.78	1.77	0.03	1.60	2.22	0.02
7	19.30	1	19.30	-0.73	0.53	1.56	2.53	0.93	1.40	2.99	1.33
22	20.80	2	41.60	0.77	1.19	1.65	2.17	0.01	1.60	2.22	0.02
23	20.90	2	41.80	0.87	1.52	1.87	1.49	0.17	1.80	1.58	0.11
24	21.00	4	84.00	0.97	3.78	2.08	0.98	9.38	2.00	1.08	7.90
25	21.10	0	0.00	1.07	0.00	2.30	0.61	0.61	2.20	0.71	0.71
26	21.20	1	21.20	1.17	1.37	2.51	0.36	1.11	2.40	0.45	0.68
27											
28	SUMS-|	100	2002.80		21.54	30.87		22.58			20.92
29											
30			SAMPLE		SAMPLE	ASSUMED		ASSUMED	SAMPLE		ASSUMED
31			MEAN		STD DEV	MEAN		STD DEV	CHI SQ		CHI SQ
32			20.028		0.47	20.00		0.50	1.03		0.87
33											
34					@SQRT	SAMPLE		ASSUMED			
35			INTERVAL		2*@PI	DEG FREE		DEG FREE			
36			0.10		2.51	22.00		24.00			

FIGURE 7. *The normal distribution curve is so common that certain of its characteristics have achieved "rule of thumb" status. One such series of rules says that given enough measurements two-thirds of them will fall within one standard deviation of the mean; 95% will fall within two standard deviations; and 97% within three standard deviations. Thus, given the mean and standard deviation in the sample used in this article, that is, 20.03 and .46, 68% of the calculators will fail within between 19.56 and 20.49 months (20.03 ± .46); 95% of the calculators will fail between 19.10 and 20.96 months; 97% will fail between 18.63 and 21.43 months; and the probability that a calculator will last longer than 20.028 months is 50%.*

Now, after labelling columns A and B as shown in Figure 7, enter the values from Table 1 in A3 . . . A26 and B3 . . . B26. The remaining columns are calculated from columns A and B.

The first calculation to make is of the mean or average life of a calculator in months. That's calculated with the following expression:

$$\mathit{MEAN\ LIFE} = \frac{\mathit{@SUM(TIME * FAILURES)}}{\mathit{@SUM(FAILURES)}}$$

which means that we must first multiply the number of FAILURES by TIME, add the column, and divide the result by the sum of the FAILURES. The first part of that formula is calculated by multiplying column A and column B. Enter and replicate:

```
>C3:A3*B3®/R:C4 . . . C26:RR
>B28:@SUM(B3 . . . B26)®/R:C28:RR
>E30:+C28/B28
```

Those entries show that the mean life of a calculator in the sample taken is around 20 months.

Since all the calculators in the sample did not fail at the same time, you have to consider the variations in their failure times. Therefore you need to evaluate the standard deviation. One of the values that is basic to that calculation is TIME minus the MEAN LIFE, which is entered and replicated in column D as follows:

```
>D3:+A3-C30®/R:D4 . . . D26:RN
```

In general terms, the calculation for standard deviation is:

$$\mathit{STANDARD\ DEVIATION} =$$

$$\mathit{@SQRT}\left(\frac{\mathit{@SUM((TIME\text{-}MEAN)^{\wedge}2 * FAILURES)}}{\mathit{@SUM(FAILURES)\text{-}1}}\right)$$

Column D contains the calculation of the term, (TIME − MEAN), and so to square that term you can multiply the column by itself and then by column B to yield (TIME − MEAN)^2∗FAILURES. That also serves to reduce recalculation time. Enter and replicate:

```
>E3:+D3*D3*B3®/R:D4 . . . D26:RRR
```

Now find the sum. Enter:

```
>E28:@SUM(E3 . . . E26)
```

At E31 calculate the standard deviation with the entry:

```
>E31:@SQRT(E28/(B28-1))
```

So, knowing that on the average each calculator would last 20 months plus or minus a standard deviation of .47 month, it appears you could prudently guarantee the calculators for 18 months. But the prudence of that decision assumes that the sample you tested really represents all the calculators you build. You have to ask if that's a safe assumption.

Since you don't build calculators to find out how long they will last, but to sell them, you cannot test every one to find out the precise pattern of failure. You can, however, assume with some safety that the failures for all calculators you built would fall along a normal distribution (or gaussian) curve. Such curves commonly describe measurements that are taken in both scientific and industrial situations. If the sample you have tested is representative, then the failures in that sample should also describe a normal distribution.

One way to find out whether the sample is representative is to perform a Chi-square test.

Calculating Chi-square

Actually, what you would like to do now is see how well the data for the 100 sample calculators agrees with the normal distribution assumed for all calculators. Chi-square describes the degree to which the results of a test correspond to the results expected. If it's reasonable to predict that the pattern of all calculator failures will be a normal distribution curve, then to find out how useful our sample is, we have to find out how closely it approximates the same curve. If the two are the same, then Chi-square will equal one. That is rarely the case, though.

What is also important to understand is that values of Chi-square as high as 2 or as low as .3 indicate that the sample is not really representative of all of the calculators you build.

The general formula for Chi-square calls for the introduction of two more new terms, degrees of freedom, which is identified below as DEGR FREE, and the normal distribution function, referred to as NDF. The general formula for Chi-square, then, is:

$$\text{CHI SQUARE} = \frac{(1/\text{DEGR FREE}) * @\text{SUM}(\text{FREQUENCY} - \text{NDF})\hat{\ }2}{\text{NDF}}$$

Whenever you perform a statistical analysis you usually use both actual observations and estimates based on the data in the sample population. Each time you use an estimate you operate at one more remove from reality. Degrees of freedom measures the effect of using estimates. The more it involves estimates, the less reliable your next conclusion. The effect of estimation is accounted for by reducing the number of observations by the number of estimates. To calculate Chi-square for all calculators built assumes no estimates, and so the number of observations is not reduced. However, the mean and the standard deviation have been estimated from the data, and so the number of observations should be reduced by two. Enter:

```
>F36:@COUNT(A3 . . . A26)-2
>H36:@COUNT(A3 . . . A26)
```

NDF, the normal distribution function, is considerably more complex, though in large part already on the sheet. Its general expression is:

$$\begin{aligned}\text{NDF} = {} & @\text{SUM(FAILURES)} * (\text{INTERVAL/STD DEV}) * \\ & @\text{EXP}(-.5 * (@\text{ABS}(\text{TIME} - \text{MEAN}) \\ & /\text{STD DEV})\hat{\ }2)/@\text{SQRT}(2 * @\text{PI})\end{aligned}$$

Most of the elements of the normal distribution function have already been calculated. There are, however, two or three terms that must be generated before we can complete the analysis.

The first new term is @SQRT(2 * @PI), which is a constant. Enter it at E36:

```
> E36 :@SQRT(2*@PI)
```

The INTERVAL is the distance, in this case in time, between the observations. That can be calculated simply by subtraction or entered directly as a value. Enter:

```
> C36 :+A26-A25
```

Remember that although you calculated the mean and the standard distribution, those values refer to the observed failures of the 100-calculator sample. Since you will also have to calculate Chi-square for all calculators you build, you will have to assume a mean life and a standard deviation. Enter those assumptions at F32 and H32 as follows:

```
>F32:20
>H32:.5
```

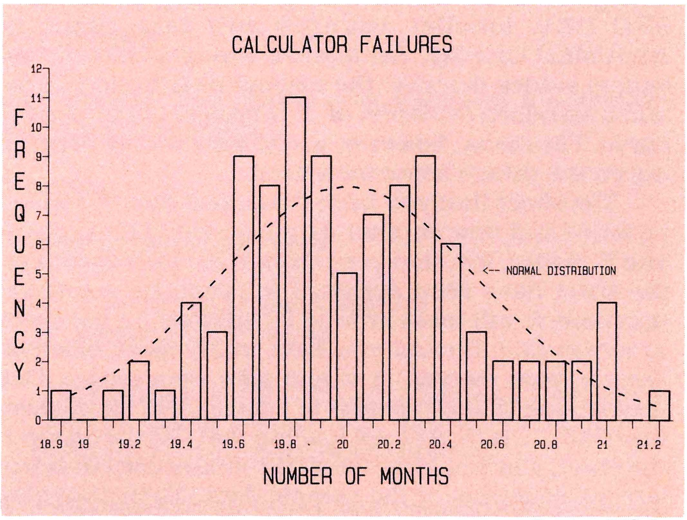
The expression needed to calculate NDF is long enough to afford quite a few opportunities to make mistakes during entry. Therefore, we've broken it down into several parts for you. The first part to enter is the @ABS(TIME – MEAN)/STD DEV term. Enter and replicate:

```
>F3:@ABS(A3-C32)/E32
>F3:/R:F4 . . . F26:RNN
```

Another reason for breaking the expression into the parts we have is that the @ABS term, which is part of the @EXP term, must be squared, and both @EXP and exponentiation operators require relatively large amounts of recalculation time. By breaking out the @ABS portion of the expression, it can be calculated separately and then multiplied by itself to reduce the time needed for recalculation.

You now have all the elements necessary to calculate the NDF, so enter and replicate:

```
>G3:+B28*(C36/E32)*@EXP(-.5*
  (F3*F3))/E36®/R:G4 . . . G26:NNNRRN
```



Courtesy BPS, Inc.

FIGURE 8. *When plotted, the data from the sample produces the bar graph shown in this figure. The normal distribution curve superimposed upon the bar graph shows that the sample roughly approximates the normal distribution.*

Now all the elements of Chi-square are on the sheet and the calculation itself can begin. Since you must take the sum of the term (FAILURES – NDF)^2/NDF before calculating Chi-square, you will have to create a column with that term. Enter and replicate:

`>H3:+B3-G3*(B3-G3)/G3`

Now total the column with the entry:

`>H28:@SUM(H3 . . . H26)`

Now it is possible to evaluate Chi-square for the test sample. Enter:

`>I32:H28/F36`

To calculate Chi-square for all the calculators you will build, assuming a mean life of 20 months and a standard deviation of .5 (both of which should be on your sheet already at F32 and H32) only require that you replicate the calculations in columns F . . . H into I . . . K. Begin by replicating row 3 only. Enter:

`>F3:/R . . . H3:I3:NRRNNRNRRNRNRR`

Next, fill the columns with the replication:

`>I3:/R . . . K3:K4 . . . K26:RNNNNNNNRRRRRRR`

Then total column K. Enter:

`>K28:@SUM(K3 . . . K26)`

Finally replicate the Chi-square calculation at I32 into K32. Enter:

`>I32:/R:K32:RR`

The Chi-square calculation for the sample tested yielded a value of 1.03 and that for all calculators 0.87. Both those values are close enough to 1 to support the contention that the test sample taken was representative. And given that, you would be quite safe if you guaranteed your calculators for 18 months.

You should be aware that this analytical technique is extremely sensitive to apparently small changes in your assumptions. If, for example, you changed the ASSUMED MEAN to 19.5 the ASSUMED CHI SQ will change to 13.68 from .87. If you change ASSUMED STD DEV, smaller changes will take place in ASSUMED CHI SQ. Remember, though, that the assumed values describe the normal distribution curve and a standard deviation of .5 is typical of the normal curve. The mean, however, would vary widely depending on the things being measured.

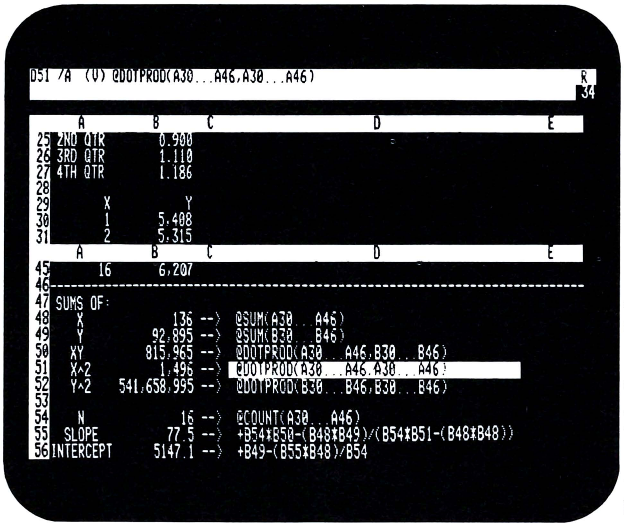
The sheet that you have developed can, of course, be saved and new or other data inserted in Columns A and B. Notice, too, that even though the expressions on the sheet have been designed to minimize recalculation time, it still takes around 20 seconds for the sheet to recalculate. Should you have many more observations in your sample, it would take even longer. One way around that problem is to create a DIF file consisting of A3 . . . H26. By then loading that DIF file on top of the sheet, you would freeze all the values used in calculating Chi-square of the sample data. Then changing the ASSUMED MEAN will require only the recalculation of the last three columns. The sheet would then recalculate in under 10 seconds. (These recalculation times, of course, are approximate and will vary from system to system, but the magnitude of the savings should remain roughly equal from system to system.)

ANOTHER LOOK AT VISICALC ADVANCED VERSION

In our last issue we introduced some of the formatting features of the VisiCalc® Advanced Version program (AV). In this issue, we'll look at one of the new features of the program, @DOTPRODuct, at some refinements of the replicate command, and at how to display expressions in AV.

@DOTPRODuct

Figure 9 shows a truncated version of one of the sheets developed for the article "What Next?" Notice that unlike the sheet shown in the figures for that article there are only two columns, X and Y, and yet we have calculated the sums of XY, X^2, and Y^2. We were able to use only those two columns and @DOTPROD to generate all the values needed for the regression analysis and the calculation of the coefficient of correlation.



```
D51 /A  (V) @DOTPROD(A30...A46,A30...A46)                          R
                                                                   34
        A           B     C                    D              E
25 2ND QTR       0.900
26 3RD QTR       1.110
27 4TH QTR       1.186
28
29        X           Y
30        1       5.408
31        2       5.315
        A           B     C                    D              E
45       16       6,207
46--------------------------------------------------------------------
47 SUMS OF:
48    X             136 -->  @SUM(A30...A46)
49    Y          92.895 -->  @SUM(B30...B46)
50   XY         815.965 -->  @DOTPROD(A30...A46,B30...B46)
51   X^2          1,496 -->  @DOTPROD(A30...A46,A30...A46)
52   Y^2    541,658,995 -->  @DOTPROD(B30...B46,B30...B46)
53
54    N              16 -->  @COUNT(A30...A46)
55  SLOPE          77.5 -->  +B54*B50-(B48*B49)/(B54*B51-(B48*B48))
56INTERCEPT      5147.1 -->  +B49-(B55*B48)/B54
```

Photograph by Sonny Tarbi.

FIGURE 9. *This screen photo shows how we have reorganized the sheet shown in Figures 3 and 4. The widths of columns A . . . E are 9, 12, 5, 40, and 9 respectively. Notice that N, SLOPE, and INTERCEPT have been centered with /ALC and that the values associated with those labels have been formatted to /AV1F and thus show one decimal place.*

The @DOTPROD function multiplies, in order, each of the elements in each of two ranges and then gives the sum of that series of products. To see how this works without actually using @DOTPROD, enter the series 1 . . . 10 in A1 . . . A10 and B1 . . . B10; at C1 multiply A1 by B1 and then replicate that expression down to C10. Then enter @SUM(C1 . . . C10) at C11. Your sheet should show 385 as a result at C11. Using @DOTPROD the column containing the results of the multiplication is unnecessary and in place of the @SUM function we would enter @DOTPROD(A1 . . . A10,B1 . . . B10).

On our sheet, the entry:

```
>B50:@DOTPROD(A30 . . . A46,
  B30 . . . B46)
```

produces XY. To produce the sums of the squares of X and Y, we have only to specify the same ranges within the function. Specifically, to produce both values we entered:

```
>B51:@DOTPROD(A30 . . . A46,
 A30 . . . A46)
>B52:@DOTPROD(B30 . . . B46,
 B30 . . . B46)
```

Notice in all cases that @DOTPROD requires that the ranges be of the same length. If they are not, the function will return ERROR.

The Replicate Command in AV

The replicate command operates in essentially the same way in AV as in earlier versions. You still specify a source and a target range and tell the program whether you wish value references to be relative or no change. Several refinements have been added to the command, however. First, if all the references are to be N (No Change) or R (Relative) you may specify that when you give the command by using the (option before the source range is specified. When you use the (option you are presented with four further choices: A, C, N, R, which allow you to specify a replication of Attributes only, Contents only, No change of references, or Relative references only.

Another important aspect of the /R command in AV concerns the replication of a range into a range in the same direction. In AV you can do so with ease. For example when we replicated the QTRLY AVERAGE and QTRLY INDEX columns in *What Next?* you'll recall that we had to complete those columns by doubling, then redoubling them. The table below shows how the columns were produced in earlier versions of the VisiCalc program and how they can be produced in the VisiCalc Advanced Version program.

VC1

```
>C4:/R:C8:RR
>C4:/R . . . C8:C12:RR

>D4:/R . . . D7:D8:RRRRRRRR
>D4:/R . . . D11:D12:RRRRRRRRRRRRRRRR
```

AV

```
>C4:/R . . . C7:C8 . . . C16:RR

>D4:/R(R) . . . D7:D8 . . . D16
```

Similarly, once we have done the basic calculations necessary to produce the X column, we can fill out the column in AV with half as many replications as before.

VC1

```
>B30:/R . . . B33:B34:RNRNRNRN
>B30:/R . . . B37:B38:RNRNRNRNRNRNRNRN
```

AV

```
>B30:/R . . . B33:B34 . . . B42:RNRNRNRN
```

Displaying Expressions

In the screen photo shown in Figure 9, column D has been made 40 characters wide, and the expressions in B48 . . . B56 have been replicated into the column with all value references set to N. We then entered:

```
>D48:/AEY
```

for Attribute: Expression: Yes, which produced the first expression. Then, we replicated only the Attributes with the following entry:

```
>D48:/R(A):D49 . . . D56
```

That produced the remaining expressions shown on the screen.

As we said in our last issue, we expect that only a few of you have upgraded to VisiCalc Advanced Version. We shall continue to feature brief pieces on AV in each issue of SATN, but for those of our readers who haven't upgraded, we shall continue to emphasize applications and features that will be of interest and use to all VisiCalc users.

RELATED PRODUCTS CHECKLIST

The information contained in this column has been garnered from a variety of sources including dealers, press releases, manufacturers, and advertising.

No one at Software Arts, Inc. has reviewed or examined any of these products to determine whether they perform as claimed or as listed below. An inclusion in this listing does not constitute an endorsement by Software Arts, Inc. of that product. We also wish to point out that if any of the products listed alter, patch, or copy the VisiCalc® program, they could be in violation of your user licensing agreement and/or the copyright.

Since we have not reviewed any of the products, we cannot provide you with any more information than is contained in the list. If you want to learn more or you wish to purchase any of the products listed, contact your dealer first. Although we have identified distributors in some listings, many distributors do not accept orders from individuals for single copies of software or pieces of hardware.

SOFTWARE

Only software that claims to complement the VisiCalc program will be listed.

Graphics

Apple Business Graphics

- Runs on Apple II and Apple ///
- Supports DIF™ format

Package to plot data and print graphics from Apple files, including VisiCalc files. Interfaces with over 35 different kinds of plotters and printers.

Developed by Business and Professional Software, Inc., 143 Binney Street, Cambridge, MA 02142.

Distributed by Apple Computers, 10260 Bandley Drive, Cupertino, CA.

Suggested list price: $175.

BBS Business Graphics

- Runs on IBM PC

Software to draw a variety of graphic formats including line and bar graphs, pie charts, and combinations. Includes statistical functions and projection abilities. Works with color monitors, dot matrix printers, letter quality printers and plotters.

Developed and distributed by Business and Professional Software, Inc., 143 Binney Street, Cambridge, MA 02142.

Suggested retail price: $300.

Visagraph

- Runs on Radio Shack TRS-80 Model I or Model III

Graphics software to plot data from VisiCalc files, features selectable graph sizes, titles, automatic scaling, high resolution and large capacity.

Developed and distributed by Micro Software Systems, 1815 Smokewood Ave., Fullerton, CA 92631.

Suggested retail price: $79 for Model I version, $89 for Model III version.

HARDWARE

Only hardware that runs the VisiCalc program, or that enhances it, will be listed. We will not list 16 Kbyte RAM boards for Apple computers or 64 Kbyte RAM boards for the IBM PC, as there are too many to cover.

Memory Expanders

SVA 256K APP-L-CACHE

RAM card for the Apple II. Expands memory by 256 Kbytes, using 64K RAMs.

Available from Sorrento Valley Associates, Inc., 11722 Sorrento Valley Road, San Diego, CA 92121.

Saturn RAM Board

RAM board to expand the memory available for 16-sector VisiCalc up to 128 Kbytes. Software is available (at additional charge) in two versions, one for 13-sector VisiCalc programs and one for 16-sector VisiCalc programs.

Distributed by Saturn Systems, PO Box 8050, Ann Arbor, MI 48107, and Alpha Logic Business Systems, Inc., 3720 Winston Drive, Hoffman Estates, IL 60195.

Legend 128KDE, 64KDE and 64KC Cards

High density RAM cards for the Apple II. Software is available at additional cost to run the VisiCalc program.

Distributed by Legend Industries, Ltd., 2220 Scott Lake Road, Pontiac, MI 48054.

Omega Ramex-128

128 Kbyte plug-in RAM board for the Apple II. Uses a separate program, available on disk at an additional charge, to move VisiCalc models into the new memory.

Available from Omega Microware, Inc., 222 South Riverside Plaza, Chicago, IL 60606.

Suggested retail price: $499.

Other Hardware

Shadow/VET

Voice Entry Terminal for Apple II or Apple II-Plus 48K computer. Voice and keyboard entry can be interchanged.

Available from Scott Instruments, 1111 Willow Springs Drive, Denton, TX 76201.

Suggested retail price: $995.

Videx 80-column card

Plug-in card for the Apple II to give 80 screen columns rather than the usual 40 screen columns. Software is available for additional cost to run the VisiCalc program.

Distributed by Videx, Inc., 897 NW Grant Avenue, Corvallis, OR 97330.

Suggested retail price: $345.

To submit information on products (software or hardware) that support either the VisiCalc program or the DIF format for data exchange, send us the name of the product; what it does; who developed it; who markets and distributes it; the suggested retail price; if it is software, what machine(s) it runs on and whether it supports the DIF format. Send the information to:

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